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REMOVING SMUT FROM PACIFIC NORTHWEST WHEAT BY WASHING

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INTRODUCTION

Stinking smut is found to some extent wherever wheat is raised in the United States, but the disease is especially prevalent in the wheat-producing sections of the Pacific coast because of the dry-farming methods used there.

Wheat must be thoroughly cleaned of all smut before it is milled into flour, for any attempt to mill smutty wheat without removing the smut results in the production of flour with a disagreeable odor and a poor color. Bread and other products made from such flour are similarly affected.

It is usually considered unsafe to blend even slightly smutty wheat with clean wheat in an attempt to "work off" some smutty wheat without cleaning it. There is grave danger that the smutty wheat so blended will cause the whole mixture to be classified and graded as "smutty." Hence, it would seem that the only safe procedure with smutty wheat is to clean it regardless of the quantity of smut it contains and regardless of whether it is to be used directly for milling flour or is to be sold as wheat.

SMUTTY WHEAT IN PACIFIC NORTHWEST

In general there appears to have been an increase in the quantity of smut found in wheat of the Pacific Northwest from 1920 to 1924 in spite of extended publicity given to the improved control methods which have been developed by the research departments of the United States Department of Agriculture and the State agricultural colleges and experiment stations. In the 1925 season, be-

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cause of winter-killing, there was a large increase of spring-wheat seeding in the Pacific Northwest, which is usually given as the cause of the marked reduction in smut that year. It is notable that the spring wheat grown in that region contains less smut than does the winter wheat.

The Oregon State Grain Inspection Department statistics regarding smutty wheat inspected are given in Table 1. The statistics refer to wheat received and graded at Portland and Astoria, the two terminal markets in Oregon; but the figures may be considered as a good indication of the smut condition of the total wheat crop of the Pacific Northwest, including Oregon, Washington, and Idaho, as wheat from all three of these States comes to Portland. The combined wheat production of these States for the last seven years has averaged approximately 87,000,000 bushels per year. On the basis of 0.494 per cent as the average smut dockage (as shown in Table 1), it would appear that for the seven years indicated there was a yearly average of 25,786,800 pounds of smut dockage in the wheat crop of the Pacific Northwest. Incidentally, this weight of smut dockage when loaded into freight cars at 50,000 pounds per car would require 516 cars for its transportation each year from the country point to the terminal.

TABLE 1.—*Smut in wheat inspected in Oregon, 1920–1926*

Year	Wheat inspected [1]		Average percentage of smut dockage in —[2]		Computed smut dockage assessed [2]
	Total	Percentage graded smutty	Smutty wheat	Total wheat	
	Bushels	*Per cent*	*Per cent*	*Per cent*	*1,000 pounds*
1920	29,647,576	26.0	0.87	0.226	4,024
1921	41,837,348	43.5	1.01	.438	11,005
1922	23,584,432	46.5	1.10	.511	7,233
1923	36,824,093	45.9	1.40	.644	14,226
1924	20,735,973	61.5	1.48	.907	11,290
1925	26,353,935	30.4	1.06	.321	5,075
1926	33,827,563	42.5	1.18	.501	10,168
Average	30,401,560	42.3	1.16	.507	9,003
Weighted average				.494	

[1] Compiled from the annual report of the Oregon State Grain Inspection Department.
[2] Computed from statistics given in the annual report of the Oregon State Grain Inspection Department.

PREVIOUS METHOD OF REMOVING SMUT

Until recent years the use of the scouring machine was the only method commonly used in grain elevators and mills for removing smut from commercial wheat, and this method is still used to a considerable extent. Scouring is a continuous process and consists of a violent agitation of the wheat by rotating beaters in a stationary steel-jacketed cylinder. A current of air is allowed to flow to the inside of the cylinder, whence it is drawn through the wheat and out through narrow openings in the steel jacket. By this method, the smut spores and fine particles of bran, which are removed from the

wheat kernels by the scouring process, are quickly drawn through the jacket openings and away from the wheat.

To make the scouring action more effective, lime or plaster is usually added to the wheat before scouring. The lime or plaster acts as an abrasive. After being scoured the wheat has a rough, starchy feeling because of a roughened bran coat and the presence of a very small part of the lime or plaster which remains with the wheat. The test weight per bushel of the wheat is usually slightly increased by scouring. The increase in test weight is more pronounced when lime or plaster is not used.

Wheat on the Pacific coast is ordinarily very dry and brittle. Probably the most serious objection to scouring such wheat for the removal of smut is the excessive loss in weight because of the cracking and abrasion of the kernels caused by the violent action of the rotating beaters in the scourer.

The scouring method of removing smut from wheat usually is effective and is, in general, satisfactory in most cases. As scouring is a dry process, it naturally has some advantages over washing because in the washing method when smut is removed from wheat that contains a high percentage of moisture, subsequent drying of the grain may be necessary.

Scourers alone are still used extensively in mills and elevators for removing smut from commercial wheat, but the well-equipped cleaning plant should be able either to scour or to wash smutty wheat, and if the plant is located in a section in which the wheat ordinarily has a high moisture content, it should also be equipped with a commercial dryer.

PURPOSE OF THE INVESTIGATION

Investigation of washing with a single-cylinder washer for the removal of smut from wheat of the Pacific Northwest was undertaken to determine whether the washing method is effective in removing smut from wheat, to determine what effect washing has on the grading quality of the wheat, and to ascertain the economic advisability of the washing method as compared with the dry scouring method for removing smut from commercial wheat or wheat that is bought and sold on the market.

WASHING METHOD OF CLEANING SMUTTY WHEAT

The washing method of removing smut from wheat has been in use in flour mills for many years as a part of the process of preparing wheat for milling, but only in recent years has the washing method of removing smut been used in elevators for preparing wheat for the domestic and export trade.

WASHING SMUTTY WHEAT FOR MILLING

The washing of wheat for grinding in a flour mill is different in some respects from the washing of commercial wheat. The purpose of the washing process in a mill is to leave the washed wheat not only free of smut but also in the most favorable condition for grinding. Roughly speaking, this means that the wheat after washing should be as free from smut and dirt as possible; and if the wheat

is to be ground immediately it should contain a relatively large, but definite, percentage of moisture. Therefore, when the original moisture content of the wheat is below what is needed for milling, the addition of water is necessary and may be at least partly accomplished in the washing process.

WASHING WITH A DOUBLE-CYLINDER WASHER

The double-cylinder washer (fig. 1) is the type generally used for washing wheat in flour mills. In the mixing tank, A, on the washer shown in Figure 1, and in cross section in Figure 2, the wheat to be washed is thoroughly drenched before it enters the lower cylinder of the washer. Wheat that enters the mixing tank drops into a

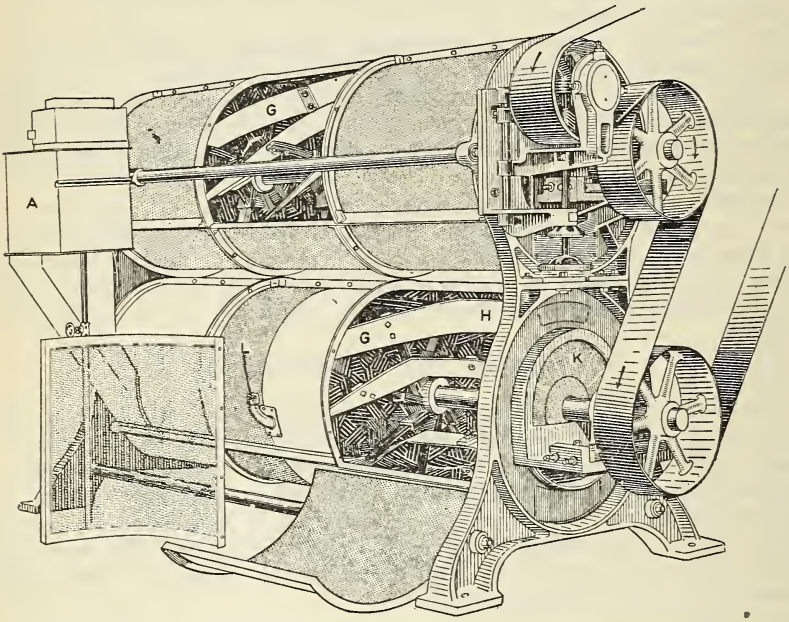

FIGURE 1.—Double-cylinder grain-washing machine. The inside construction and arrangement of the essential parts are shown

hopper from which its flow is controlled by a valve. Water from a pipe, controlled by a valve, is spouted on to a baffle board along which the grain coming from the hopper also slides. A second baffle board, changing the direction of flow, thoroughly mixes the wheat and water. After this mixing the drenched grain enters the lower cylinder of the washer.

The beaters, G, of the lower cylinder (fig. 1), rotate rapidly in the direction indicated by the arrow on the pulley. After entering the lower cylinder from tank A, the wheat is violently agitated in its drenched condition and is propelled toward the pulley end of the cylinder by the spiral beaters G. When the wheat reaches the first perforated section of the cylinder, the whizzing action removes the wash water and its accumulated smut spores and dirt from the wheat. Water for rinsing the wheat enters the washer through pipe L.

Here, for a short interval, the wheat is again drenched, is mixed, and then is whizzed over another perforated section of the cylinder, which removes the rinsing water. The wheat is then thrown by centrifugal force from the straight portion, H, of the beaters through a connecting pipe (not shown in fig. 1) into the upper cylinder.

No water is admitted into the upper cylinder, made of perforated metal throughout its entire length and known as the whizzer or drier. In this cylinder the spiral beaters violently rub the wheat against the inside of the cylinder, throwing off the moisture that is on the surface of the kernels and at the same time propelling it toward the left end of the cylinder, where it is expelled from the machine through a pipe not shown in Figure 1. The vanes, K, in the ends of the cylinders rotate with the main shaft and produce a movement of air into the cylinders, which passes out through the perforations with the wash water leaving the cylinders. The perforations in the cylinders are round and are approximately five-and-one-half sixty-fourths of an inch in diameter.

When they are cleaning wheat for grinding, millers are conscious of the fact that they are preparing a food product that will have passed beyond the possibility of further cleansing when it is ground into flour. No effort is spared to make the wheat as clean before it is ground as are foods that are prepared in the home.

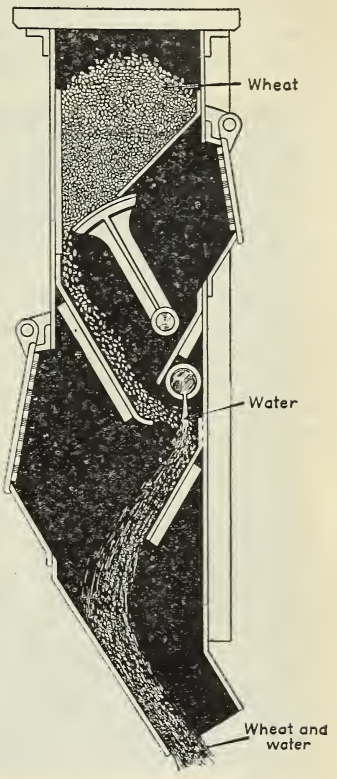

FIGURE 2.—Mixing tank for washing machine. Cross section of a standard mixing tank in which smutty wheat is thoroughly drenched with water before it enters the washer

WASHING SMUTTY WHEAT FOR COMMERCE

Wheat usually changes hands many times before it is finally ground into flour, and each year many millions of bushels of smutty wheat are cleaned and shipped to foreign and domestic markets to be ground into flour. In transactions that involve smutty wheat the early elimination of the smut, without needlessly lowering the grade and market value of the wheat, is highly desirable. The price of wheat is usually based on its class and grade according to established Federal grain standards. These standards specify certain limiting factors which assure the buyer that the wheat of any grade is not below a certain quality.

Anyone who attempts to remove smut from the wheat by any process which will put the wheat in such condition that it can be sold as clean wheat, without the dockages and discounts attached because of smut, must be paid for the operation, at least to an extent sufficient to offset the cost of the cleaning. In the process of cleaning smutty wheat, if some grading factor is so affected that the wheat is thrown

into a grade lower than that on which it was bought, a part of the advantage of removing the smut may be lost, and the operation may even at times prove unprofitable.

Drying the wheat is recommended for any wheat that has after washing a moisture content in excess of 13.5 per cent for winter wheats and in excess of 14 per cent for spring and durum wheats.

Wheat that, because of having been washed, has a dull, frosted appearance, or an objectionable odor, or an unnatural feeling, may, when it is inspected and graded, have the notation "washed" or "treated" added to the inspection certificate by the grain inspector. As such a notation on the inspection certificate may cause the wheat to sell for a lower price than could be obtained for it if it were not labeled "washed" or "treated" every wheat-washer operator endeavors so to handle his washed wheat that it will not receive a "washed" or "treated" notation when it is inspected by a grain inspector.

The dull, frosted appearance of wheat, sometimes caused by washing, is due to a roughening of the bran coat of the wheat. Soft wheats are more likely to roughen when washed than are hard wheats. Some operators improve the appearance of badly roughened washed wheat by a light, dry scouring after it has been tempered in storage, following washing. Some washed wheat has an objectionable odor. This odor is probably caused by incomplete removal of the smut in washing; and is also likely to be found in wheat that has been stored with too much moisture after having been washed.

WASHING WITH A SINGLE-CYLINDER WASHER

When the washing of smutty wheat for export was first considered on the west coast, the necessity of preserving the fresh appearance of the wheat presented a serious problem in the successful use of the washing process. After considerable experimenting it became evident to some of the progressive grain-cleaner operators of the Pacific Northwest that the double-cylinder washing machine gave smutty wheat for commerce an unnecessarily severe scrubbing which seriously affected its appearance. Therefore, at Astoria, Oreg., a single-cylinder washer was installed and used at the municipal elevator. The results of the experiment were seemingly satisfactory.

As a result of this experiment at Astoria, a battery of single-cylinder washers was installed in the municipal terminal No. 4 grain elevator at Portland, Oreg. (which will be referred to, hereafter, as the Portland elevator). The washing equipment at the Portland elevator consisted, during the period of these investigations, of two double-cylinder wheat washers redesigned and built into four single-cylinder washers so that complete washing of the wheat was done by each of the four cylinders. Figure 3 shows the two double-cylinder washers as changed to four single-cylinder washers and installed at the Portland elevator. By the change in design the washing capacity of the two double-cylinder machines was practically doubled, the total wheat-washing capacity being from 1,000 to 1,600 bushels per hour.

In the two single-cylinder washers shown in the foreground of Figure 3, smutty wheat from the storage bins in the workhouse enters the two washers through spout S, the end of which terminates in a kind of hopper which is open at the top. A valve, H, controlled by a handle, regulates the feed of grain into the lower cylinder. Another valve at V similarly controls the feed into the upper cylinder. As viewed in Figure 3, the beaters in each of the cylinders rotate counterclockwise, causing the wheat to travel from left to right during the washing process. The washed wheat leaves the top cylinder through the pipe P, and unites with the washed wheat coming from the lower cylinder through the pipe Q. The washed wheat from the two cylinders then passes through the pipe R, which leads

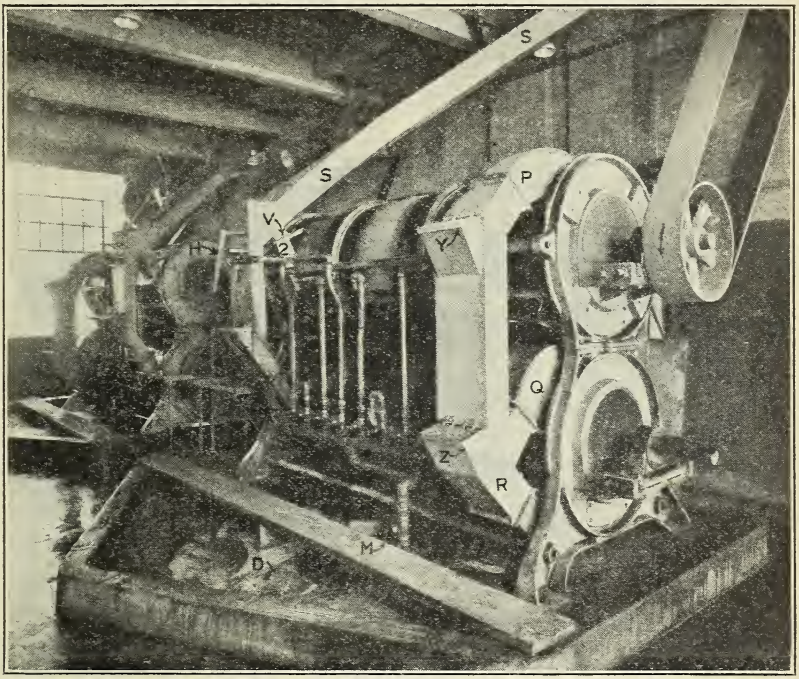

FIGURE 3.—Grain-washing machines. Two double-cylinder washers, redesigned and installed to operate as four single-cylinder washers

to the elevating leg in the basement of the elevator. Three doors, X, Y, and Z, provide handholes for sampling the grain.

Water for the two cylinders is admitted through the main valve, M, at the bottom of the washer and is distributed to various points in the two cylinders by the eight auxiliary valves located in a line above the main valve. The water for the initial drenching of the wheat is admitted to the wheat stream at points 1 and 2 for the lower and upper cylinder, respectively. The rinsing water is admitted to the cylinders at the various points along their length as shown. The smut-laden water, resulting from the washing and rinsing, which also carries any solid matter and wheat germs that

are removed from the wheat, flows off the washer casing into the drain pipe at D and thence to a sewer. The pure city water used by these washers is metered, which makes it possible to determine the quantity of water used per bushel of wheat washed.

Wheat-washing machines now on the market are mostly of the single-cylinder type. Figure 4 illustrates a single-cylinder washer built as such at the factory.

STUDY OF EFFECTS OF WASHING WHEAT

The engineer of the commission of public docks of Portland, Oreg., who was responsible for the grain-elevator operation, requested the United States Department of Agriculture to study the washing plant at terminal No. 4 as to cost of operation and effectiveness of the single-cylinder washers in removing smut from wheat. The Federal grain-investigations office at Portland undertook the work, and much

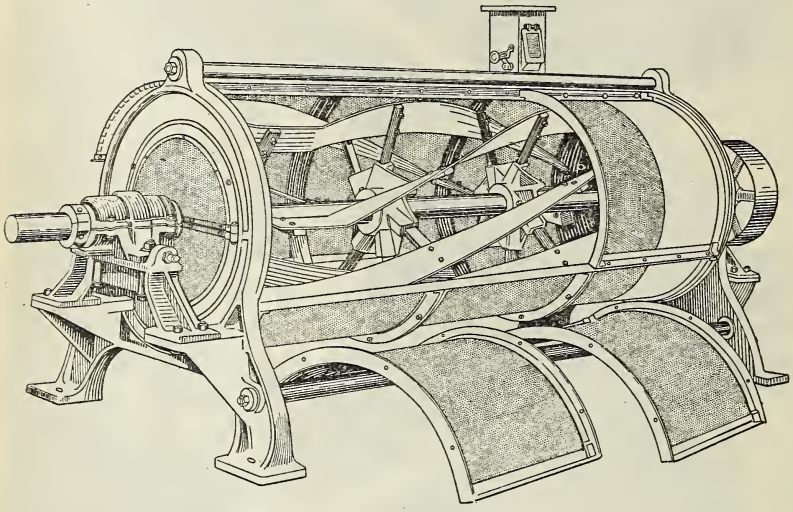

FIGURE 4.—Single-cylinder grain-washing machine

of the following material is taken from the report of the department investigators.

The work at the elevator was done by two men of the grain division of the Bureau of Agricultural Economics, with the occasional aid of men of the elevator force and the men of the Oregon State Grain Inspection Department. With this cooperation, it was possible in nearly all cases to obtain complete information on the entire 140 car lots of smutty wheat washed at the elevator during the period of the investigation.

One of the investigators worked at the elevator, taking samples and records, while the other remained in the laboratory and analyzed the wheat samples as they came from the elevator. The work at the elevator consisted of sampling the various lots of wheat and keeping a record of such items as the identity of the wheats being cleaned, washed, scoured, transferred, or shipped; rate of cleaning and rate of washing; net working and the idle time of the cleaner and wash-

ers; the number of men employed and the time worked; the water-meter readings; and the weight of the wheat before and after cleaning and washing.

At the Portland elevator all smutty grain was run over a grain cleaner before going to either scourers or washers. This cleaning of the grain before scouring or washing is not necessarily a part of the smut-removing process, although it is usually desirable to clean smutty wheat before washing.

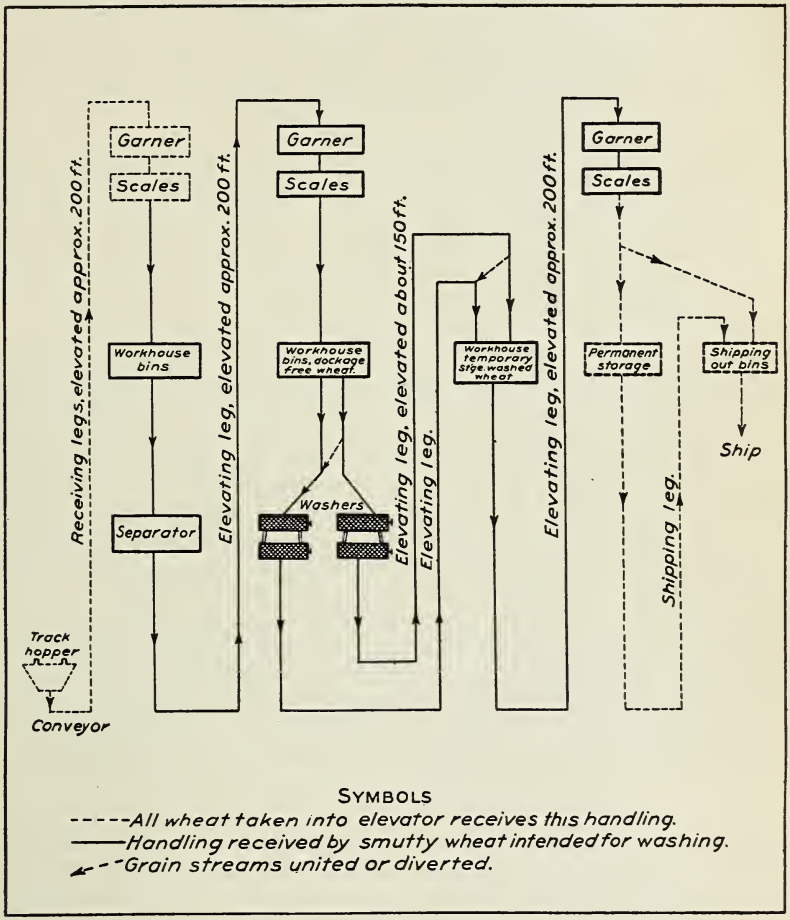

FIGURE 5.—FLOW SHEET FOR GRAIN ELEVATOR

Equipment used and the method of handling the grain in the process of washing smutty wheat at the municipal terminal No. 4 grain elevator at Portland, Oreg.

The flow sheet (fig. 5) shows graphically the usual procedure followed at the elevator in handling and disposing of smutty wheat before and after washing. The portion of the diagram drawn in dotted lines shows the handling that all wheat, whether smutty or clean, receives at the elevator. The portion drawn with solid lines

represents the extra handling that is required by wheat that is smutty and is to be washed. Figure 5 also shows the points at which samples were taken in the investigations.

SAMPLING THE WHEAT BEFORE AND AFTER WASHING

The wheat as received at the elevator was sampled officially by the Oregon State Grain Inspection Department in the ordinary manner. Additional samples were obtained by sampling the grain streams at frequent regular intervals in accordance with standard methods of sampling. In all cases the comparatively large samples that were accumulated (sometimes as much as a half bushel) were split down to laboratory size by means of a Boerner sampler and were placed in air-tight cans to prevent moisture changes in the samples before they were tested and analyzed.

Two samples of each lot of smutty wheat were obtained before the wheat was washed, and two samples of each lot were obtained after the washing was completed. The first before-washing sample was the original official sample obtained from the State grain inspection department and represented the wheat as it was received from the cars at the elevator track shed. The second before-washing sample was obtained at the point where smutty wheat entered the receiving hopper of the washer. Since all of the wheat to be washed was first run through a cleaner to remove foreign materials, including many smut balls, the second sample (rather than the original sample obtained by the inspection department) represents the exact condition of the wheat before washing. The third sample in the series, which was the first after-washing sample, was taken as the wheat left the washer and represents the condition of the wheat immediately after washing. The fourth sample in the series, which was the second after-washing sample, was taken as the wheat was being transferred from its temporary storage in a workhouse bin to permanent storage in the storage annex of the elevator.

In outlining the studies, it was planned to secure a fifth sample as the wheat was being placed on a ship, but the identity of the washed wheat when placed in large, permanent storage bins could not be preserved, and for this reason no reliable data, to compare with the results obtained from washing the individual lots, could be obtained regarding the wheat as it was being shipped out of the elevator.

LABORATORY ANALYSIS OF WHEAT SAMPLES

Laboratory analyses of the wheat samples were made to show the change in the grading factors that were produced by the actual washing and handling which the wheat received incident to the washing process. Each sample was analyzed for the following factors: Smut in the form of balls and pieces of balls, and smut spores per kernel smeared on the wheat kernels; actual smut dockage and assessed smut dockage; actual dockage and assessed dockage; foreign material other than dockage; moisture content; test weight per bushel; numerical grade; cracked wheat; and germination. All factors except dockage, moisture content, and germination were studied on the basis of dockage-free wheat. The germination tests, made by the Oregon Agricultural College, were made on the basis of whole kernels of wheat only.

It should be mentioned here that the Pacific Northwest uses the smut-dockage system of grading smutty wheat, which method is described in paragraph (*a*) of the Federal grain standards for wheat [1] under the specifications for Smutty Wheat, as follows:

(*a*) Before the determination of smut dockage as provided in this paragraph, the wheat shall be graded and designated according to the grade requirements of the standard applicable to such wheat if it were not smutty, except that smut balls shall not be considered as foreign material other than dockage. The loss in weight caused by the removal of smut from the wheat shall be ascertained by scouring, washing, or otherwise, and shall be calculated in terms of percentage based on the total weight of the grain free from dockage. The percentage so calculated shall be stated in terms of whole per cent and half per cent. A fraction of a per cent when equal to, or greater than, a half shall be treated as a half, and when less than half shall be disregarded. The percentage of the "smut dockage" so calculated and stated shall be added to the grade designation preceding the statement of dockage, if any.

In determining the smut dockage, the removal of smut from the wheat samples is accomplished by means of a laboratory-size scouring machine similar to, but smaller than, the commercial scouring machine described. All smut dockages later referred to in this bulletin were determined by use of the laboratory scourer.

EFFECTIVENESS OF WASHER IN THE REMOVAL OF SMUT FROM WHEAT

The analysis of the actual smut content of the wheat samples taken before and after washing is of scientific interest in connection with the efficiency of the single-cylinder washer in removing smut from wheat. The results of the study may also be of interest in estimating the value of this type of machine for cleaning smutty wheat for milling purposes.

The before-washing and after-washing samples for each lot were analyzed for smut by weighing the whole balls and the pieces of balls, and by computing the weight of the smut spores on the kernels by means of a blood-count apparatus. The weight of the smut thus determined was reduced to a percentage basis. From the smut-spore-count studies of the wheat before washing and after washing, it appears that the wheat as it entered the washer contained smut spores in the form of balls, pieces of balls, and loose spores on the kernels in quantities ranging from 15,230 to 93,380 spores per kernel. The number of spores averaged 33,980 per kernel. The computations were on the basis of 30 kernels per gram of wheat, and 375,000,000 smut spores to the gram of smut. (The grain investigations office had found through previous studies that an averaged-sized smut ball under Pacific Northwest conditions weighs about 0.01 gram, or, in other words, there are 100 average-sized smut balls per gram weight of smut. One average-sized smut ball, therefore, contains approximately 3,750,000 spores.) After the washing process the wheat contained from 1,237 to 8,194 spores per kernel, an average of 4,115. The percentage of smut spores and balls removed by washing ranged from 69.5 to 96.6 per cent and averaged 86.9 per cent of the total smut in the wheat.

[1] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS. HANDBOOK OF OFFICIAL GRAIN STANDARDS, JANUARY, 1928.

From these data it may be concluded that the same percentage; namely, 86.9 per cent, of the total weight of smut was removed from the smutty wheat.

It was found that in the total quantity of wheat involved in these investigations there was a total of 24,720 pounds, or 0.236 per cent by weight, of actual smut in the form of smut balls and smut spores on the wheat immediately before washing. Hence, on an average 86.9 per cent of 24,720 pounds, or 21,482 pounds of smut, was removed from the smutty wheat by washing. This weight of smut constituted approximately 20 per cent of the total weight of material taken from the wheat by the washing process.

EFFECT ON SMUT DOCKAGE AND APPEARANCE

Although the analysis just reported deals with the absolute reduction of smut in the wheat studied, manifestly the principal objective in washing smutty wheat for trade and export use is to reduce the smut content of the wheat below that which would cause the wheat to be graded "smutty." To meet the requirements for wheat to be considered as free from smut dockage under the Federal wheat standards, the wheat, after cleaning, must not have a distinct odor of smut, nor can there be smut in the wheat in the form of spores, balls, or pieces of balls in excess of a quantity equal to two average-sized smut balls in 50 grams of wheat.

Only licensed grain inspectors can officially grade grain; hence, in order to ascertain the official grade of the samples of the washed wheat as to smut dockage, the samples were submitted to licensed grain inspectors. In every case the washed wheat was pronounced "free from smut dockage" after the washing process. Therefore, as a factor affecting the commercial value of the wheat based on the Federal standards, the single-cylinder washer, in these cases, proved to be entirely effective in removing smut dockage.

It is a well-known fact that the handling through elevator legs, spouts, cleaners, and bins of smutty wheat that contains fragile smut balls, will tend to crush many of the smut balls and to smear the spores on the wheat kernels. The samples of wheat taken in the washing investigation provided an excellent means for making a study of the tendency of the handling of smutty wheat to increase its smut dockage. The grain handling referred to in this study occurred between the taking of the original sample of smutty wheat as received and the taking of the sample immediately before washing. This handling consisted of an elevation of the grain from track pit to the garners, a drop from the garners to the scales hopper, a transfer from the scales to a workhouse bin, drawing of the grain from the workhouse and its passage through a cleaner, a reelevation to another workhouse bin, and a drawing from this bin to supply the washer.

A comparison was made between the smut dockage and actual smut-spore content found in the sample taken at the track pit with the same factors in the samples taken just before the wheat entered the washer. Obviously there was less actual smut (including balls and loose spores) in the wheat after it had been cleaned by the Monitor cleaner than before, as a considerable part of the material

removed by the cleaner was smut. Nevertheless the wheat kernels themselves carried an average of 26,800 spores each after the wheat was handled and passed through a cleaner in preparation for washing, whereas an average of only 12,600 spores per kernel was found on the wheat as received at the elevator. Obviously many of the fragile smut balls were crushed or broken while the grain was being handled, and the loose spores were smeared on the wheat kernels.

The increase in smut spores thus smeared on the wheat kernels as a result of this handling caused an increase in smut dockage. The average smut dockage assessed by the Oregon State Grain Inspection Department on the 140 cars of wheat as received was 1.62 per cent and ranged from 0.5 to 4.5 per cent. The smut dockage was increased to an average of 3.02 per cent and ranged from 1 to 5 per cent as the wheat came to the washer. The increase in assessed smut dockage due to the handling operations ranged from 0.1 to 2.16 per cent.

The increase in assessed smut dockage is accounted for by the fact that in determining the smut dockage with the laboratory-scouring device it becomes necessary to scour wheat that is badly smut smeared a number of times. The effect of the more severe scouring with either a laboratory or a commercial-size scourer is to remove more weight of bran from the wheat kernels and thus to increase the assessed smut dockage on the wheat.

The increase in the number of smut spores adhering to the kernels, resulting from the handling of the grain as it was being prepared for washing, was not objectionable in so far as the washing process was concerned, as it is desirable to have the smut balls broken up before washing, in order to permit their easy removal from the wheat by the water. Washers are occasionally equipped with a device called a smut breaker, the function of which is to break up all smut balls thoroughly before the smutty wheat enters the washer. In many instances throughout the United States smutty wheat is put through scouring machines for the purpose of breaking up the smut balls before washing.

Smutty wheat that is graded on the smut-dockage basis is liable to have its smut dockage increased as the grain is handled through elevators, even though the actual quantity of smut in the wheat has not been increased. It is only when smutty wheat is to be stored and delivered again as smutty wheat that the matter of increase of smut dockage due to breaking of smut balls in handling becomes serious. It seems desirable, therefore, where washing machines are not available to remove the smut from the wheat either at an early stage in its handling or where smutty wheat that is to be again sold as smutty wheat must be placed in storage, to keep to a minimum the number of handlings it receives.

EFFECT ON DOCKAGE CONTENT

The original smutty wheat contained an average of only 0.32 per cent of assessable foreign material or weed seed (foul) dockage. Only a few of the lots contained 1 per cent or more dockage, which is the minimum assessable in grading. Practically all of the as-

sessable foul dockage found in these lots was removed from the grain by cleaning. This means that no lot contained as much as 1 per cent of this kind of material after cleaning.

The actual foul dockage (meaning the presence of such material computed to the nearest 0.1 per cent) as distinguished from the assessable dockage averaged 0.79 per cent before the wheat was run through a cleaner and 0.47 per cent after it was cleaned. This latter percentage represents the quantity of dockage material the smutty wheat contained as it entered the washer. The washing process further reduced the actual dockage material content to an average of only 0.36 per cent. The foul dockage in smutty wheat usually includes some free smut spores and some whole and broken smut balls. The foul dockage in this case also contained rachis, some grains other than wheat, and weed seeds. Some of this material is removed in washing, but it is obvious that when such materials are larger than the perforations of the washer casing, they are not appreciably reduced in quantity by the washing process.

FOREIGN MATERIAL OTHER THAN DOCKAGE

The amount of "foreign material other than dockage" in the wheat involved in the study was very small. In no case did this material become a factor on which the grade of the wheat could have been based. The average foreign material other than dockage present in the wheat, as received, was 0.19 per cent. After being run over the cleaner, this material was reduced to 0.11 per cent; and after the wheat had been washed, there was found to be an average of only 0.08 per cent of foreign material other than dockage.

MOISTURE CONTENT OF THE WHEAT

The moisture content of the wheat involved in these investigations as received at the elevator ranged from 8.16 to 10.15 per cent and averaged 8.64 per cent. The moisture content of the wheat after being washed ranged from 10.1 to 11.95 per cent, and averaged 10.78 per cent, indicating an average increase in moisture content of 2.14 per cent due to the washing process. These figures suggest why it is not ordinarily necessary to dry Pacific coast wheat that has been washed for the removal of smut. The moisture content of the wheat grown in that region is ordinarily so low and the increase in the moisture due to washing so comparatively small that artificial drying is seldom necessary. But these conditions do not prevail every year. The 1927 crop of wheat produced in the Pacific Northwest contained on an average a high moisture content.

Washed wheat which contains moisture in excess of the quantity considered safe for storage should be commercially dried to a lower moisture content, to put it into condition for safe storage, and to meet the moisture content requirements of the higher grades as specified in the Federal grain standards.

Wheat obtained directly from a washer is always wet to the touch, and it appears wet. This is because the washing operation retains the wheat in the washer a remarkably short time and the moisture necessarily remaining on the wheat immediately after washing is all on the surface of the kernels. After a short period of storage this

moisture penetrates the kernels and gradually equalizes throughout the mass of the wheat. When the moisture of the washed wheat is equalized, and the wheat has a low moisture content, the feeling of wetness has disappeared and the wheat again feels dry and hard. There is an increase in moisture content due to washing, but in a good job of washing the increase is so small in the case of originally very dry wheat that after tempering in storage, the increased moisture is not noticeable on inspection and can be detected only by a moisture test of the wheat.

TEST WEIGHT PER BUSHEL

The average test weight of the dockage-free wheat as received at the elevator was 57.3 pounds per bushel. After the wheat was run through a cleaner where some of the foreign material and some of the smut were taken out of the grain, the average test weight was increased to 57.8 pounds per bushel. The wheat as it came from the washer, with the moisture principally on the surface of the kernels, showed a reduction in test weight to an average of 55.9 pounds per bushel, which was a reduction of 1.9 pounds from the test weight at which it entered the washer. The test weight immediately after washing is given no significance except for comparison with later tests of the same wheat to show the effect of tempering in the temporary storage bins. The tempering of approximately 24 hours which the wheat received in temporary storage brought the test weight up to an average of 56.6 pounds per bushel, which was a loss of 1.2 pounds per bushel as compared with its test weight on entering the washer.

The loss in test weight between the smutty wheat as received at the elevator and the washed wheat after the short period of temporary storage ranged from 0.1 to 2.7 pounds per bushel in the various lots and averaged 0.7 pound per bushel.

It is rather generally understood among grain-washer operators that the tendency of wheat to lose test weight upon being washed is largely caused by the increased moisture content of the washed wheat. Dry wheat will ordinarily decrease less in test weight when washed than will wheat of a higher moisture content, other conditions being equal.

This fact is accounted for in two ways: (1) Dry wheat absorbs less moisture on being washed than does the higher-moisture-content wheat, and (2) it was found in these investigations that with the same percentage of change in moisture, dry wheat will show a smaller change in test weight than will high-moisture wheat. In the case of very dry wheat, it has frequently occurred that there was no loss in test weight because of washing.

Another factor affecting the change of test weight in the washing of smutty wheat is the removal of the smut itself. Smut spores on the wheat kernels reduce the test weight, as they tend to make the surface of the kernels more or less sticky and the smutty kernels will not pack as closely in the test kettle as they would if no smut spores were present. The removal of the smut from the wheat during the washing process has a tendency to increase the test weight of the wheat, but on the other hand the water that the wheat absorbs

during the washing process tends to reduce the test weight to an even greater extent with a final result that the wheat usually has a lower test weight after washing than before washing.

In considering any method of removing smut from wheat and its effect on the test weight of smutty wheat, the above facts, which show that the test weight of smutty wheat is not the true test weight of the natural wheat, should be taken into account.

NUMERICAL GRADE OF THE WHEAT

In comparing the numerical grade of the lots of wheat as received at the elevator as graded by the Oregon State Grain Inspection Department, with the grade of the wheat after being cleaned, washed, and held in temporary storage for a brief time, the following result was obtained:

Of the 140 car lots washed, 115 cars, or 82 per cent of the lots, were of the same numerical grade after washing as before washing. Twenty-five cars, or 18 per cent of the lots, were one numerical grade lower, after washing. Of these 25 cars, the grade of 12 cars was changed from No. 2 to No. 3 and the grade of 13 cars was changed from No. 3 to No. 4.

Attention is called to the fact that in each case the grading factor which determined the grade in all of this wheat was its test weight per bushel.

TENDENCY OF WASHING TO CRACK THE WHEAT

As very dry wheat is brittle, it is in danger of being cracked in the scouring and washing machines. It is a well-known fact that the dry scourer has often caused excessive loss both in weight and in quality of wheat, by cracking the wheat.

During this study the washer had only a slight tendency to crack the wheat. In studying this effect, the samples were picked by hand, and all broken wheat was included with the cracked wheat. The average quantity of cracked grain in the wheat as received at the elevator amounted to 3.07 per cent. After the wheat had been run over a cleaner, the percentage of cracked kernels was 2.97. After the wheat had been washed, the cracked grains amounted to 4.73 per cent. This is an increase of 1.76 per cent based on the weight of the wheat as received.

EFFECT OF WASHING ON THE GERMINATION OF WHEAT

The Oregon Agricultural College conducted germination tests on samples of the wheat taken both before and after having been washed. The wheat before being washed showed a germinating quality that ranged from 91.5 to 99 per cent, averaging 95.4 per cent. After washing, the same wheat showed a germinating quality ranging from 87.5 to 94.5 per cent and averaged 90.7 per cent. In these tests whole kernels only were used.

It is a recognized fact that the dry-scouring method of removing smut from wheat makes the wheat entirely unfit for seed purposes. The ruinous effect of scouring wheat to be used for seed was indicated in this study by the condition of one car of wheat which was

run through the dry-scouring machine to break the hard smut balls before washing. This sample, which was not included in the above summary, had originally a germinating quality of 95 per cent, which was reduced to 71 per cent by dry scouring and further reduced to 53 per cent by washing. The great reduction in germination quality, from 71 to 53 per cent as a result of washing the scoured wheat is probably due to the fact that many of the germs had been loosened by the dry scouring so that they were easily removed and washed away when the wheat was subjected to the washing process.

INCREASE IN WEIGHT

The receiving weights of the car lots of wheat which included dockage were obtained from the records of the elevator which showed the official weights as given by the Oregon State Grain Inspection Department. In most cases it was possible to obtain the weight of the wheat after cleaning. The wheat was not weighed immediately after it was washed, but in all cases was weighed when it was being transferred to the permanent storage bins after it had been in temporary storage in the workhouse bins. There was an increase of weight caused by moisture that had been absorbed by the wheat as a result of washing which was counteracted to a certain extent by a loss in weight of the solid materials washed and cleaned from the wheat. The washing process increased the gross weight of the wheat by 141,991 pounds, which is an increase of 1.35 per cent over the weight of the wheat as it entered the washer.

The effect of the washing process upon the weight of merchantable wheat, figured from the official receiving weights and grades and the weight after washing, was determined as follows:

The scale weight of the original smutty wheat which also contained some dockage as received at the elevator was 10,587,755 pounds, against which there was an average assessed foul dockage of 0.32 per cent. Deducting 33,881 pounds, the computed assessed dockage, leaves 10,553,874 pounds of dockage-free wheat with smut dockage. Deducting the average smut dockage of 1.62 per cent, or 170,973 pounds, assessed against the smutty wheat, leaves 10,382,901 pounds, the computed weight of merchantable wheat received at the elevator.

After being washed the wheat was free of both assessable dockage and assessable smut dockage and weighed 10,652,672 pounds, which was all merchantable wheat; hence the gain in weight of the merchantable wheat, due to washing, was 269,771 pounds, which is a gain of 2.60 per cent of the weight of the original merchantable wheat as received at the elevator.

REDUCTION OF DRY MATTER

Sufficient data were obtained from the washing tests to estimate by calculation the quantity of solid or dry matter removed from the grain by the washing process. The dry matter lost during the washing process consisted chiefly of smut, wheat germs that had been knocked off the kernels, hairs from the brush end of the kernels, bran from the outer layers of the kernels, and other bits of foreign material.

The total scale weight of the wheat immediately before washing was 10,510,681 pounds. This weight is somewhat higher than the computed weight of merchantable wheat received at the elevator for the reason that fractions of a per cent of dockage are not considered in deductions in weight for dockage. The weight of dry matter in this grain, based on its average moisture content of 8.64 per cent before washing, was therefore 9,602,558 pounds. The weight of the wheat after washing was 10,652,672 pounds. The weight of dry matter in this grain, based on its moisture content of 10.78 per cent after washing, was 9,504,314 pounds. Hence it appears that there was a loss of 98,244 pounds of dry matter due to the washing process. Of the original receiving weight 91.36 per cent was dry matter (100−8.64=91.36 per cent). Hence, to reduce the dry matter removed to the basis of the moisture in the grain as received, divide 98,244 pounds by 0.9136, which gives 107,535 pounds. This is a loss of 1.02 per cent of the weight of the wheat entering the washer.

COST OF LABOR, POWER, AND WATER FOR WASHING SMUTTY WHEAT

The labor involved in the washing of smutty wheat at the Portland elevator was performed principally by four men who gave either all or part of their time to this work. To determine the labor costs it was necessary to make some estimates based on observation as to the proportion of time spent by certain of the men on work other than that directly connected with the washing. The period included in the study is from 8 a. m. September 9, to 12 noon on September 27, 1924, during which time there were 128 working hours.

The following statements as to the amount of time each of the men devoted to the work of washing the smutty wheat are based largely on the judgment of the observers.

A foreman, who supervised the washing and made the necessary adjustments as to rate of feed and quantity of water to be used, gave about three-fourths of his time to the work of washing during the period under study. One assistant gave all of his time to the operation of the grain cleaner and the washers. A third workman gave practically all of his time to sacking the screenings removed from the smutty wheat by a cleaner. The duties of the fourth workman consisted of making transfers of washed wheat and other wheats from the various bins in the workhouse and the storage annex. The amount of time he gave to transferring the washed wheat was determined from a record of the length of time required to discharge washed grain from the bins, an allowance of approximately 10 minutes per transfer being made for setting the spouts and attending to other arrangements required for the transfer of washed wheat from a workhouse bin to a bin in the storage annex.

It was assumed that the number of extra elevations required by washed wheat as compared with the elevations given clean wheat is indicative of the proportion of time given to the work of washing by the men whose duties are general about the plant and who are only indirectly connected with the washing operations. Car lots of wheat requiring neither washing nor scouring, receive but one elevation and are sent directly from the scales to the permanent

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CORRECTED STATEMENT REGARDING COST OF WASHING SMUTTY WHEAT.

The summary in Table 3, page 19, of Circular 81, Removing Smut from Pacific Northwest Wheat by Washing, issued in August, 1929, should read as follows:

Labor cost of washing–	
Total	$404.84
Per ton	.0765
Per bushel	.00229

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storage bins. Wheat that is to be washed receives three additional elevations before it is put into permanent storage bins. Wheat that is to be scoured but not washed receives two additional elevations before permanent binning. All wheat shipped out of the elevator receives one additional elevation in delivering it from the storage bins to freight cars or ships.

The four items were weighted, for the time over which the study extended, by taking the product of the weight of grain in each item and the number of times elevated. (Table 2.)

TABLE 2.—*Quantity of wheat processed and number of elevations in each process, September 9–27, 1924*

Item	Quantity	Times elevated	Weighted value
	Million pounds	*Number*	
Wheat:			
Receipts	26	1	26
Washed	10	3	30
Scoured	5	2	10
Shipments	26	1	26
Total			92

Ratio of weighted value of 30 for washed wheat to total weighted value of 92 for all the wheat is approximately one-third.

As there were 128 working hours during the period of the investigation, 43 hours was assumed to be the time that the last three men referred to in Table 3 gave to handling the washed wheat.

TABLE 3.—*Estimated labor cost of washing smutty wheat, showing the number, location, and rate of pay of the men directly and indirectly connected with the washing process*

Location of men connected with washing process	Men employed	Time required for washing	Rate of pay per hour [1]	Labor cost
	Number	*Hours*	*Dollars*	*Dollars*
Directly connected:				
Foreman in charge of washers	1	96	1.14	109.44
Assistant at washers and warehouse cleaners	1	128	.70	89.60
At cleaner sacking dockage from wheat	1	128	.70	89.60
Drawing washed wheat from warehouse bins	1	37	.70	25.90
Indirectly connected:				
Foreman on scale floor	1	43	.70	30.10
Assistant on scale, transfer, and bin floors	1	43	.70	30.10
Oiler for all machinery	1	43	.70	30.10
Total	7	518		404.84

Summary:		
Total wheat washed	short tons	5,293.9
Labor cost of washing—		
Total		$404.84
Per ton		$7.65
Per bushel		$0.229
Man-hours required for washing—		
Total	hours	518
Per ton	do	0.10

[1] Eight-hour day.

Costs of power for washing smutty wheat will vary with different installations and unit costs. At the Portland elevator, where a rate of 2 cents per kilowatt-hour is paid for power, the cost of power was 0.095 cent per bushel, or 3.17 cents per ton of wheat washed.

The opinions of the washer operators vary as to the quantity of water necessary for washing wheat of different varieties and varying quantities of smut. The cost of water at different plants varies. At the Portland elevator water cost 7 cents per 100 cubic feet and was used during the period of investigations at the average rate of 4.2 gallons per bushel of wheat washed. On this basis the water cost was 0.039 cent per bushel, or 1.31 cents per ton of wheat washed.

The total cost of labor, power, and water was 0.364 cent per bushel, or 12.13 cents per ton of smutty wheat washed, of which 26 per cent was for power, 11 per cent for water, and 63 per cent for labor. Attention is called to the fact that this cost does not include overhead charges. The tariffs charged at Portland elevator for washing smutty wheat, which of course do include overhead charges, are given in Table 6.

ESTIMATED GAIN IN VALUE OF WHEAT STUDIED IN WASHING EXPERIMENTS

One of the purposes of this study was to determine approximately how the money value of the smutty wheat involved in the washing investigation was affected by the changes produced in the wheat by the washing process. The increase in weight and the changes in test weight per bushel, together with the removal of smut dockage and smut discounts, were the principal factors affecting the commercial value of the wheat.

The change in weight determined the number of bushels of wheat that was gained or lost by washing, but changes in the test weight per bushel somewhat affected the grade of the wheat and hence the price per bushel that the wheat would sell for on the market. By washing the smut from the wheat, the smut dockages and the smutting charges were eliminated as factors in the market value of the washed wheat.

The prices per bushel used for determining the value of each lot of wheat both before and after washing were taken from price quotations furnished on September 19, 1924, by the Merchants' Exchange Daily Price Bulletin, of Portland, Oreg. Any other day's price schedule would have been just as satisfactory as the one chosen. These quotations are on the basis of Federal grades and are for wheat in sacks, bulk wheat prices being at that time 3 cents per bushel less than prices for sacked wheat. Table 4 shows the prices, in bulk, for the six different kinds of wheat studied.

TABLE 4.—*Price per bushel of bulk wheat, by kind and weight, at Portland, Oreg., September 19, 1924*

Kind of wheat	Price per bushel of wheat having a test weight of—						
	60 pounds	59 pounds	58 pounds	57 pounds	56 pounds	55 pounds	54 pounds
Dark hard winter	$1.35	$1.34	$1.33	$1.32	$1.31	$1.30	$1.28
Hard winter	1.31	1.30	1.29	1.28	1.27	1.26	1.24
Western red	1.285	1.275	1.265	1.255	1.245	1.235	1.215
Western white	1.38	1.37	1.36	1.35	1.34	1.33	1.31
Soft white	1.39	1.38	1.37	1.36	1.35	1.34	1.32
Hard white	1.40	1.39	1.38	1.37	1.36	1.35	1.33

TABLE 5.—*Schedule of grain dealers' charges for cleaning smutty wheat of varying percentages of smut dockage*

Range of smut dockage, (percentage)	Cleaning charge per ton for bulk wheat [1]
0.5 to 1, inclusive	$0.45
1.5 to 3, inclusive	.50
3.5 to 7, inclusive	.80
7.5 to 15, inclusive	1.00

[1] Charge for cleaning sacked wheat is 30 cents per ton additional.

The cost of having smutty wheat washed at the Portland elevator also varies with the assessed smut dockage on the wheat. The rates for washing bulk wheat are given in Table 6.

TABLE 6.—*Schedule of charges of elevator at terminal No. 4 for washing smutty wheat of varying percentages of smut dockage*

Range of smut dockage (percentage)	Washing charge per ton for bulk wheat [1]
0.5 to 3, inclusive	$0.35
3.5 to 7, inclusive	.60
7.5 to 15, inclusive	.75

[1] Washing charge includes running the wheat over the Monitor cleaner and either the scouring or washing machine.

In determining the value of the wheat as received at the market the following procedure was carried out:

All wheat values were based on bulk wheat, thus eliminating the value of the sack as an economic factor.

Assessed foul dockage (referred to as "Dockage" in the Federal wheat standards), if any, was first subtracted from the receiving car-lot net weight of the wheat in bulk. The amount of smut dockage was then ascertained by applying the percentage of officially assessed smut dockage to the weight of the wheat that was free of assessed foul dockage. The smut dockage subtracted from the dockage-free weight gave the weight of the wheat purchased by the buyer. The smut discount or cleaning charge assessed against the wheat (see Table 5) was determined on the basis of the receiving net weight of each lot of wheat according to the amount of its assessed smut dockage.

The cost of washing the smutty wheat was determined on the basis of the receiving weight and assessed smut dockage of the grain. (Table 6.) The buying and selling price of the wheat was based on its test weight per bushel. (Table 4.) It was assumed that all changes in the quality of the wheat were indicated in the changes in its grading factors.

The buying price of the smutty wheat was based on the grade and weight of each separate car. The selling price of the washed wheat

was necessarily based on the grade and weight of each separate order. When many carloads of wheat are thrown together and run through the washer as a single lot, the carloads lose their identity, and the lot is termed an "order" at the elevator. There were 11 orders in the study, each order consisting of from 1 to 23 carloads.

Table 7 shows the market value at Portland, Oreg., of the 11 orders of smutty wheat studied in the wheat-washing investigation at the Portland elevator, the market value of the same wheat after washing, and the cleaning charges as applied to the wheat according to the published schedules.

TABLE 7.—*Change in market value of the wheat studied due to removal of smut by washing*

Order No.	Receiving weight of wheat with smut	Average assessed smut dockage	Value of wheat, net weight			Cost of removing smut from wheat			Profit from washing wheat [1]	
			Before washing	After washing	Increase due to washing	Charge to producer by purchaser	Charge to purchaser by elevator	Profit to purchaser	Total per order	Per ton
	Tons	*Per ct.*								*Cents*
76	411.61	1.84	$17,986.35	$18,306.81	$320.46	$224.15	$160.34	$63.81	$384.27	93.4
91	493.39	1.40	21,957.84	22,354.79	396.95	246.66	186.06	60.60	457.55	92.7
110	43.50	1.00	1,909.08	1,938.15	29.07	19.58	15.23	4.35	33.42	76.8
115	928.26	2.11	37,942.28	38,899.65	957.37	469.26	335.31	133.95	1,091.32	117.6
121	780.80	1.94	34,479.48	34,572.80	93.32	437.44	324.26	113.18	206.50	26.4
125	878.13	1.06	39,048.86	39,702.73	653.87	386.80	314.09	72.71	726.58	82.7
141	584.39	1.05	26,079.82	26,304.07	224.25	272.84	204.54	68.30	292.55	50.1
146	622.47	.84	27,601.54	28,086.27	484.73	282.22	217.87	64.35	549.08	88.2
147	37.42	4.00	1,651.20	1,695.74	44.54	29.93	22.45	7.48	52.02	139.0
149	259.71	2.49	11,391.82	11,510.06	118.24	141.93	100.96	40.97	159.21	61.3
151	254.23	2.96	11,132.89	11,464.91	332.02	164.72	121.37	43.35	375.37	147.6
Total or average	5,293.91	[2] 1.62	231,181.16	234,835.98	3,654.82	2,675.53	2,002.48	673.05	4,327.87	[2] [3] 81.8

[1] Increase due to washing plus profit to purchaser.
[2] Weighted average.
[3] The average profit of 81.8 cents per ton is equivalent to approximately 2.5 cents per bushel.

The results of the calculations shown in Table 7, indicate that the smutty wheat studied, if purchased at the regular trade discounts based on the schedule of charges for washing smutty wheat (Table 5), and washed at the cost shown by the tariffs charged at the elevator (Table 6), and then sold on the same price schedule as that on which it was purchased, would net the merchandiser of the wheat an average profit of 81.8 cents per ton, or approximately 2.5 cents per bushel.

The graphical study of the relation of assessed smut dockage to profit realized (fig. 6), indicates that the higher profits were made on the wheats that had the higher percentages of assessed smut dockage.

REQUIREMENTS OF A WASHING PLANT

For successful washing of smutty wheat it is essential to have a good washer, plenty of pure water, a satisfactory means of disposing of the refuse from the washer, and an operator who knows the business of washing. The business of washing includes a thorough knowledge of the machine itself, of the Federal grades on which the

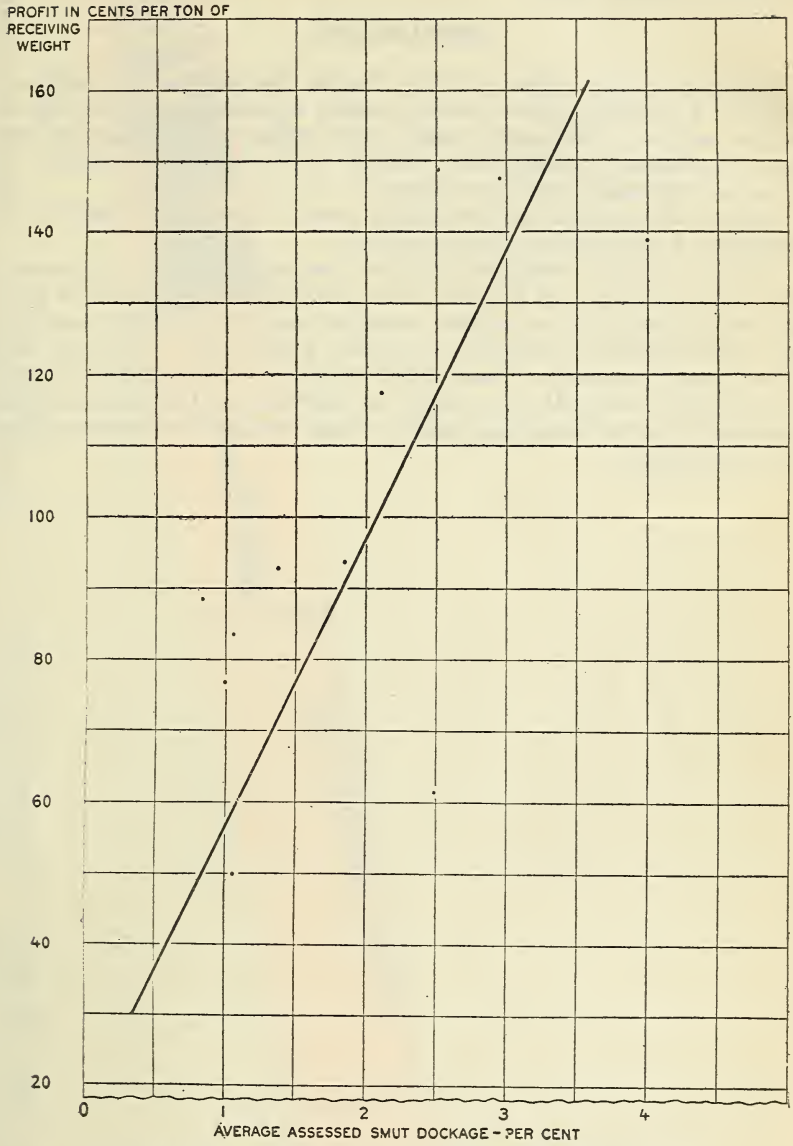

FIGURE 6.—PROFIT RESULTING FROM WASHING SMUTTY WHEAT

Relation between assessed smut dockage and profit per ton as a result of washing smutty wheat, as shown in Table 7

wheat is bought and sold, and of the characteristic reactions of the varieties and condition of wheat to be washed to the washing process. To wash smutty wheat without injuring its appearance or depressing its grade requires skill.

CONCLUSIONS

Washing smutty wheat of the Pacific Northwest with either a single or a double cylinder wheat washer appears to be a highly desirable method of removing smut from wheat for commercial purposes (including milling and mixing with smut-free wheat), for domestic shipments, and for export.

Among the reasons for removing smut at an early stage in the handling of wheat after threshing are:

(1) To avoid the complications that frequently arise in connection with smut dockage and the discounts caused by the presence of smut, (2) to eliminate at the earliest possible moment the extra handling and special binning required for smutty wheat, (3) to prevent clean wheat from becoming contaminated at places where smutty wheat is also handled, and (4) to prevent an increase in the smut dockage resulting from the handling smutty wheat receives in transportation and in elevators.

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